NASA Facts

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External Tank Thermal Protection System

The Space Shuttle's External Tank is covered with special spray-on foam insulation that serves to insulate the tank before and during launch. The foam is one of two components in the External Tank's Thermal Protection System, or TPS.

There are two basic Thermal Protection Systems on the External Tank: One is low-density, closed-cell foam that looks much like Styrofoam ®, the most recognizable form of foam polystyrene. The other Thermal Protection System component is a denser composite material called ablator, made of silicone resins and cork and resembling corkboard. An ablator is a material that dissipates heat by eroding.

The closed-cell foam used on the tank acreage is a Spray On Foam Insulation often referred to by its acronym as SOFI (pronounced soo-FEE). The composite material is Super Lightweight Ablator, known as SLA (pronounced slaw).

The External Tank uses ablators on areas that are subjected to extreme heat, such as the ogive, or the top of the tank, and on the lines that feed the liquid oxygen and liquid hydrogen to the Shuttle's Main Engines.

The closed-cell foam used on the tank was developed to keep the propellants that fuel the Shuttle's three Main Engines at optimum temperature. It keeps the Shuttle's liquid hydrogen fuel at minus 423 degrees Fahrenheit and the liquid oxygen tank at minus 297 degrees Fahrenheit -- even as the tank sits under the hot Florida sun -- while preventing a buildup of ice on the outside of the tank.

The foam insulation must also be durable enough to endure a 180-day stay at the launch pad, withstand temperatures up to 115 degrees Fahrenheit, humidity as high as 100 percent, and resist sand, salt, fog, rain, solar radiation and even fungus. Then, during launch, the foam must tolerate temperatures as high as 1,200 degrees Fahrenheit generated by aerodynamic friction and rocket exhaust. Finally, when the External Tank returns to Earth and begins reentry into the atmosphere -- about 30 minutes after launch -- the foam helps hold the tank together even as temperatures and tank pressurization inside work to break up the tank, allowing it to disintegrate over a remote ocean location.

Though the foam insulation on the majority of the tank is only 1-inch thick, it adds 4,823 pounds to the tank's weight. Insulation on the liquid hydrogen tank is somewhat thicker -- between 1.5 to 2 inches thick. Though the foam's density varies with the type, an average density is about 2.4 pounds per cubic foot.

The tank's foam is polyurethane-type foam composed of five primary ingredients: polymeric isocyanate or isocyanurate, a flame retardant, a surfactant, a blowing agent, and a catalyst. A surfactant controls the surface tension of a liquid. The blowing agent – originally CFC 11-- creates the foam's cellular structure by making millions of tiny bubbles or foam cells.

Application of the foam, whether automated by computer or hand-sprayed, is designed to meet NASA's requirements for finish, thickness, roughness, density, strength and adhesion. As in most assembly production situations, the foam is applied in specially designed, environmentally controlled spray cells and sprayed in several phases, often over a period of several weeks. Prior to spraying, the foam's raw material and mechanical properties are tested to assure it meets NASA specifications. Multiple visual inspections of all foam

surfaces are also performed after the spraying is complete.

Most of the foam is applied at the Lockheed Martin's Michoud Assembly Facility in New Orleans when the tank is manufactured. However, the "closeout" areas, or final areas applied, are done either by hand or spraying at the Kennedy Space Center in Cape Canaveral, Fla.

There are four specially engineered closed-cell foams used on the tank. The larger sections of the tank are covered in NCFI 24-124, NCFI is an acronym for North Carolina Foam Industries; NCFI 24 accounts for 77 percent of the total foam used on the tank.

NCFI 24-57, which has a different formulation than NCFI 24-124, is used on the aft dome, or bottom, of the liquid hydrogen tank. PDL 1034, a hand-poured foam used for filling odd-shaped cavities, and BX 250/265 foam is used on the tank's "closeout" areas. During the early days of the External Tank's development, PDL was an acronym for Product Development Laboratory, the first supplier of the foam.

NCFI 24-124, NCFI 24-57 and BX 250/265 are all mechanically sprayed foams, though BX 250/265 is manually-applied, or hand-sprayed in some areas.

Environmental Protection Agency

In 1987, the United States and 45 other nations adopted the "Montreal Protocol on Substances that Deplete the Ozone Layer." Under the Protocol, class I ozone depleting compounds, such as Chlorofluorocarbon 11 known as CFC 11 -- the Freon-based blowing agent used in the production of the External Tank's foam -- was to be phased out of production by the end of 1995. Production of these compounds after 1995 is allowed only by "Essential Use Exemption" and must have Montreal Protocol approval.

After extensive testing the External Tank Project proposed as the CFC 11 replacement hydro chlorofluorocarbon HCFC 141b, a blowing agent friendlier to the environment, as the CFC 11 replacement. At the same time, the Environmental Protection Agency allowed the External Tank program to continue use of stockpiled supplies of CFC 11until HCFC 141b was certified for use on the Space Shuttle and phased in.

However, in 1999, the EPA proposed to expand its regulations by implementing a ban on nonessential products that release class I ozone-depleting substances under section 610 of the Clean Air Act. Under the proposed rule, sale and distribution of BX 250, used to insulate part of the External Tank, would have been banned because it contains CFC 11. NASA asked the EPA to revise the proposed rule to provide an exemption for BX 250 and other foam containing CFC 11 used in applications associated with space vehicles.

The EPA allowed the exemption but limited it to the Thermal Protection System of the Shuttle's External Tank and only allowed the use of CFC 11 as a blowing agent when no other chlorofluorocarbons are used in the foam product.

The "new" foam containing HCFC 141b was first used on the liquid hydrogen tank aft dome of ET-82 and flew on STS-79 in 1996. The foam was implemented on the tank's acreage, or its larger portions, beginning with ET-88, which flew on STS-86 in 1997. In December 2001, BX-265, which contains HCFC 141b, first flew as a replacement of BX-250. However BX250 continued to be flown as BX-265 was implemented step wise through the manufacturing process.